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1 Long-term effects of pregnancy and childbirth on sleep satisfaction and duration of first-time and
2 experienced mothers and fathers.

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14

15

Abstract

16 Study Objectives: To examine the changes in mothers' and fathers' sleep satisfaction and
17 sleep duration across pre-pregnancy, pregnancy, and the postpartum period of up to six years
18 after birth; it also sought to determine potential protective and risk factors for sleep during that
19 time.

20 Methods: Participants in a large population-representative panel study from Germany
21 reported sleep satisfaction and sleep duration in yearly interviews. During the observation period
22 (2008–2015), 2,541 women and 2,118 men reported the birth of their first, second, or third child
23 and provided longitudinal data for analysis. Fixed-effects regression models were used to
24 analyze changes in sleep associated with childbirth.

25 Results: Sleep satisfaction and duration sharply declined with childbirth and reached a
26 nadir during the first three months postpartum, with women more strongly affected (sleep
27 satisfaction reduction compared with pre-pregnancy: women, 1.81 points on a 0 to 10 scale, $d =$
28 0.79 vs. men, 0.37 points, $d = 0.16$; sleep duration reduction compared with pre-pregnancy:
29 women, 62 min, $d = 0.90$ vs. men, 13 min, $d = 0.19$). In both women and men, sleep satisfaction
30 and duration did not fully recover for up to six years after the birth of their first child.
31 Breastfeeding was associated with a slight decrease in maternal sleep satisfaction (0.72 points, d
32 = 0.32) and duration (14 min, $d = 0.21$). Parental age, household income, and dual vs. single
33 parenting were unrelated, or only very weakly related, to improved sleep.

34 Conclusion: Following the sharp decline in sleep satisfaction and duration in the first
35 months postpartum, neither mothers' nor fathers' sleep fully recovers to pre-pregnancy levels up
36 to six years after the birth of their first child.

37 Keywords: Pregnancy, Childbirth, Sleep Satisfaction, Sleep Duration, Postpartum,
38 Development

39

40

Statement of Significance

41 The costs of having children include drastic short-term consequences for maternal sleep,
42 with a nadir in sleep satisfaction and duration during the first three postpartum months. After the
43 first child, neither mothers' nor fathers' sleep satisfaction or duration fully recovers, even when
44 their children reach preschool age (4–6 years postpartum). Sleep effects are more pronounced in
45 first-time parents compared with experienced parents, in mothers compared with fathers, and in
46 breastfeeding compared to bottle-feeding mothers. Higher socio-economic status (household
47 income) and psychosocial factors (dual vs. single parenting) do not appear to protect against
48 these postpartum sleep changes.

49

50

Introduction

51 Poor sleep quality and insufficient sleep are highly prevalent during pregnancy and after
52 childbirth¹⁻⁸. Although sleep disturbances have been linked with adverse birth outcomes^{9, 10} and
53 poor postpartum mental health^{3, 11-14}, intra-individual changes in maternal and paternal sleep
54 across pre-pregnancy, pregnancy, and the postpartum years remain poorly described.

55 Existing longitudinal studies have shown that from late pregnancy onwards, insomnia
56 symptoms remain highly prevalent and sleep duration decreases^{15, 16}, with first-time mothers
57 more strongly affected than those experiencing their second or third childbirth³. During late
58 pregnancy, sleep onset insomnia symptoms are more prevalent compared to the postpartum
59 period, whereas sleep maintenance insomnia symptoms are more prevalent postpartum than
60 during pregnancy¹⁶. While paternal sleep is also affected, there are indications that maternal
61 sleep is more highly fragmented¹⁷, includes longer periods spent awake after sleep onset¹⁸, and
62 leads to greater neurobehavioral performance deficits, such as decreased psychomotor vigilance
63¹⁷. Slight improvements in sleep quality are typically reported around weeks 10–12 postpartum³,
64¹⁹ and, consistent with this, the percentage of mothers with insomnia symptoms decreases from
65 approximately 60% at week 8 postpartum to 40% at two years postpartum¹⁶. However, the exact
66 course of sleep recovery as individuals' parental roles mature is yet to be explored.

67 Further, little is known regarding the impact of protective and risk factors on sleep
68 disturbances during pregnancy and the postpartum years; most previous research has considered
69 the effects of breastfeeding on maternal sleep, with inconsistent findings. While one study
70 showed greater sleep fragmentation among breastfeeding women¹⁵, others have not found sleep
71 duration or quality differences between women using different feeding methods⁷, or even longer

72 sleep duration among breastfeeding mothers²⁰ (for a review see Montgomery-Downs and
73 colleagues²¹).

74 The role of some commonplace socio-demographic and psychosocial variables have not
75 been investigated in detail either. For example, the extent to which parental age and parity may
76 play a role in amplifying or buffering the effect of pregnancy and childbirth on sleep. One would
77 also expect that variables representing higher socio-economic status (higher household income,
78 homeownership) would protect against sleep disturbance, insofar as they are known to decrease
79 stress levels generally²². It also makes sense to reason that living with a partner (i.e. dual
80 parenting vs. single parenting) may be protective. Compared with single parenting, dual
81 parenting involves higher levels of direct, practical support that might protect sleep (e.g. the
82 partner may assist with nocturnal feedings) and/or emotional support, which may decrease
83 perception of stress and thereby protect sleep^{23, 24}. Clarity on the role of these variables would
84 help interpret the effect of pregnancy and childbirth on sleep within a socio-economical context.

85 Further limiting our current understanding of sleep during pregnancy and after childbirth
86 is that most investigators have used convenience samples, while population-representative
87 samples have rarely been assessed. Existing studies with representative samples have been based
88 on cohorts of pregnant women from hospitals with a geographically limited catchment area^{3, 16};
89 no previous study has been based on a sample representative of a whole nation's population.

90 Identifying the precise timing and trends in, and factors underlying, sleep changes during
91 and after pregnancy, would inform the development of evidence-based interventions for
92 preventing or ameliorating the effects of pregnancy and childbirth on parental sleep. In the
93 present study, we aimed to address gaps in the literature by taking advantage of a large,
94 longitudinal panel study that represents the entire adult German population and by analyzing

95 intra-individual change across time using fixed-effects regression models. First, we examined
96 whether mothers' and fathers' sleep satisfaction and duration decrease across pre-pregnancy,
97 pregnancy, and the postpartum periods, with the expectation that mothers' sleep satisfaction and
98 duration would decline during pregnancy and reach a nadir during early postpartum, while
99 fathers' sleep satisfaction and duration would not be affected during pregnancy and less strongly
100 affected postpartum compared to mothers. Second, we determined whether and when mothers'
101 and fathers' sleep satisfaction and duration improved following childbirth, with the expectation
102 that sleep satisfaction and duration should have reached baseline levels, after controlling for age,
103 by the time the child reached their preschool years (4–6 years postpartum). Finally, we examined
104 the roles of potential protective and risk factors for mothers' and fathers' sleep satisfaction and
105 duration during pregnancy and the postpartum years, including socio-demographic background
106 variables (maternal and paternal age, parity, household income, and homeownership), infant
107 feeding practices (breastfeeding), and psycho-social variables (dual vs. single parenting).

108 **Methods**

109 *Database Source*

110 The data were drawn from the German Socio-Economic Panel (SOEP; Version 32.1;
111 German Institute for Economic Research), an ongoing, nationally-representative, longitudinal
112 study of private households in Germany. All members of the selected households aged 18 years
113 and older were asked to participate in yearly interviews. Households were initially chosen using
114 a multistage random sampling technique with regional clustering; later, some refreshment
115 samples were added to increase the sample size and maintain the representativeness of the data
116 for the entire population of Germany. In addition, new household members (e.g., new partners or
117 grown-up children) were invited to join the study and were also interviewed during the yearly

118 assessment sessions. To minimize attrition, individuals were followed even in cases of relocation
119 or a split in the household.

120 We used the measures of sleep satisfaction and duration collected during the annual
121 interviews for eight waves of the SOEP (2008 to 2015). Comprehensive information about data
122 collection, design, participants, variables, and assessment procedures have been described
123 elsewhere²⁵. All data were collected by a professional fieldwork organization (Kantar Public,
124 Munich). The interview methodology of the SOEP is based on a set of pre-tested questionnaires
125 for households and individuals. Generally, an interviewer tries to obtain face-to-face interviews
126 with all members of a given survey household. All participants provided informed consent;
127 ethical permission was granted by the Scientific Advisory Board of DIW Berlin. Scientific use of
128 the SOEP is available to universities and research institutes. There have been no previous
129 publications using SOEP data addressing the topics presented herein.

130 *Participants*

131 The sample included 2,541 women and 2,118 men who reported the birth of their first,
132 second, or third child during the study period, lived in Germany, and contributed longitudinal
133 data (i.e., at least two available data points on either sleep satisfaction or sleep duration); mothers
134 were on average 32.9 ($SD = 5.69$) years and fathers were on average 36.18 ($SD = 6.39$) years old;
135 with an average of 5.1 data points per participant for sleep satisfaction ($SD = 2.0$) and 4.6 for
136 sleep duration ($SD = 1.6$). Average parental age at the birth of the first child was 30.10 years (SD
137 = 5.37) for mothers and 33.26 years ($SD = 5.82$) for fathers. During the observation period
138 (2008–2015), a total of 2,128 participants reported the birth of their first child (54.37% mothers;
139 1,338 first-born children); 2,461 participants reported the birth of their second child (54.57%
140 mothers; 1,495 second-born children); and 1,032 participants reported the birth of their third

141 child (54.55% mothers; 671 third-born children). Few participants reported the birth of their
142 fourth to twelfth child. These were excluded from analyses once they reached the ‘*2 years before*
143 *childbirth*’ position with their fourth child ($N = 690$ for sleep satisfaction; $N = 656$ for sleep
144 duration; see Supplemental Materials, Table S1 for coding of childbirth for statistical analyses).
145 The total panel sample comprised $N = 38,861$ participants with longitudinal data on either sleep
146 satisfaction or sleep duration. Descriptive statistics are reported in Table 1. Participant flow
147 charts can be found in the supplemental material (see Supplemental Materials, Figures S1 & S2).

148 *Measures*

149 *Childbirth biography.* Childbirth biographies are provided by the SOEP for every
150 participant with at least one successful interview. To generate childbirth biographies, all
151 available SOEP data were used, including information from the biographical questionnaire
152 completed when each participant entered the panel; new childbirth information was collected
153 during annual interviews.

154 *Sleep satisfaction and sleep duration* were self-reported by participants during the annual
155 interviews between 2008 and 2015 (sleep duration was not included in 2014 due to interview
156 time constraints). To reduce respondent burden as much as possible, only a single item indicator
157 of sleep satisfaction was used (“How satisfied are you with your sleep?”), which was rated on an
158 11-point scale ranging from 0 (“*totally unsatisfied*”) to 10 (“*totally satisfied*”). This single item is
159 strongly correlated with validated scales that measure sleep problems and discriminates between
160 individuals affected vs. unaffected by sleep disturbance²⁶⁻²⁸. Sleep duration was assessed with
161 two items: “How many hours do you sleep on average on a normal day during the working
162 week?” and “How many hours do you sleep on a normal weekend day?” Implausibly low or high
163 values were unusual (i.e. sleep duration <2 hours: 85 observations; sleep duration >12 hours: 290

164 observations) and were replaced by a value of 2 or 12 hours, respectively. A weighted composite
 165 score was calculated as an indicator of mean sleep duration (i.e., sleep duration = $([5 \times \text{work day}$
 166 $\text{sleep duration}] + [2 \times \text{weekend sleep duration}]) / 7$).

167 *Breastfeeding.* Associations between breastfeeding and parental sleep were assessed in a
 168 subsample of parents who had their first child within the observation period (2008–2015).
 169 Information on primiparous mothers' breastfeeding was available for 1,799 parents regarding
 170 sleep satisfaction and for 1,581 parents regarding sleep duration. Whether children were
 171 exclusively breastfed, and for how long, was not asked. Up to three months after the birth of their
 172 first child, 74.48% of mothers were still breastfeeding; 48.91% of mothers were still
 173 breastfeeding when their child was four to six months old.

174 *Household income, homeownership, and single parenting.* Participants' average monthly
 175 household income after taxes was 2,829€ ($SD = 1,467€$) at the birth of the first child. Home-
 176 ownership was reported by 29.33% when their first child was born. Compared to parents living
 177 in flats let for rent, homeowners had considerably larger living spaces ($M = 132.02 \text{ m}^2$, $SD =$
 178 44.86 m^2 vs. $M = 83.23 \text{ m}^2$, $SD = 24.58 \text{ m}^2$, respectively; $p < .001$). Single parenting was defined
 179 as participants indicating that they lived alone with their child or children. Single parenthood
 180 after birth of the first child was reported by 6.11% of all primiparous parents ($n = 130$; 117
 181 women and 13 men).

182 *Statistical analyses*

183 To analyze changes in sleep satisfaction and duration over the course of pregnancy and
 184 postpartum, we used fixed-effects models²⁹, (for the same analytic approach using SOEP-data
 185 see Mata and colleagues)³⁰. Fixed-effects models exclusively analyze within-individual
 186 variation, which avoids confounding of results by time-constant unobserved heterogeneity, such

187 as social origin or genetic differences in sleep satisfaction and habitual sleep duration. Thus, the
188 participants' sleep satisfaction and duration after the birth of a child were compared to their own
189 pre-childbirth sleep satisfaction and duration. Further, the models control for all other included
190 predictors (e.g. effects of the second childbirth are controlled for effects of the first childbirth)
191 and control variables including *participant-centered age* and *age-squared*, because sleep quality
192 and duration decline with age^{31,32}.

193 To calculate these fixed-effects models, the variable of time between interviews and
194 childbirth was represented with 21 dummy variables (coded 0 or 1) within every measurement
195 wave. Within one measurement wave, dummy variables 1–7, 8–14, and 15–21 represented the
196 time between the interview and the births of the first, second, or third child, respectively. Thus,
197 there were seven dummy variables per childbirth. The dummy codes for the first childbirth were:
198 *Year 2 before 1st childbirth* = the participant's first child was born during the second year after
199 that interview; *Year 1 before 1st childbirth* = the first child was born during the year after that
200 interview; *Year 1 after 1st childbirth* = the first child was born during the year before that
201 interview; *Year 2 after 1st childbirth* = the first child was born between 1 year and 2 years before
202 that interview; *Year 3 after 1st childbirth* = the first child was born between 2 years and 3 years
203 before that interview; *Years 4 to 6 after 1st childbirth* = the first child was born between 3 years
204 and 6 years before that interview; *More than 6 years after 1st childbirth* = the first child was
205 born more than 6 years before that interview. These seven predictors were mutually exclusive.
206 The same coding procedure was used for the second and third childbirths (see Supplemental
207 Materials, Table S1).

208 Several secondary (follow-up) analyses were conducted: (1) To analyze the changes in
209 sleep satisfaction and duration across pregnancy and the first year after the birth of the first child

210 at a more fine-grained level, separate follow-up analyses were conducted with indicators for each
211 of the three pregnancy trimesters and indicators for each of the four quarters of the first year after
212 childbirth. This allowed studying the more detailed course of sleep satisfaction and duration over
213 the trimesters of pregnancy and postpartum; (2) Further follow-up analyses were conducted
214 using the birth of the first child to test potential protective or risk factors as time-varying
215 covariates: breastfeeding, maternal and paternal age, household income, homeownership, and
216 dual parenting (vs. single parenting). The analyses of the time-varying covariates related to risk
217 and protective factors rely on comparisons between coefficients of fixed-effects regression
218 models, which are derived from different subsets of participants.

219 All analyses were conducted using Stata Version 15 (College Station, Texas). All
220 Cohen's *d* score effect-sizes were calculated based on the standard deviation of the full sample.

221 *Sensitivity Analysis*

222 As is the case in all linear fixed-effects models with longitudinal data, the effect on
223 within-person change (i.e., regarding sleep satisfaction and duration) can only be calculated for
224 participants who report variation in the outcome of interest over time²⁹. In our case, variation in
225 sleep satisfaction was reported by 89.98% of all participants (with 176,061 observations in total)
226 and variation in sleep duration was reported by 86.21% of all participants (with 144,779
227 observations in total). In the entire sample, 3,848 participants did not report any change in sleep
228 satisfaction and 4,864 participants did not report any change in sleep duration. For sensitivity
229 analysis, all participants were assigned an artificial within-person change (i.e., a mean of 0.0 and
230 a SD of 0.0001) so that all participants were included in the analyses. The results of this analysis
231 (not shown) were identical to those of the sample reporting change in sleep satisfaction or sleep
232 duration.

233 Further, we compared participants with only one measurement time point and those with
 234 more measurements (i.e., participants with longitudinal data that could be used for fixed-effects
 235 analyses). There were only small differences in sleep satisfaction (7.04 vs. 6.80, respectively)
 236 and sleep duration (7.23 hours vs. 7.17 hours, respectively; all p 's < .001). These differences
 237 were further reduced after accounting for between-groups age differences (sleep satisfaction: $d =$
 238 0.04, $p < .001$; sleep duration: $d = 0.02$, $p = .11$); participants with only one observation were
 239 younger and more likely to have been newly recruited (i.e. in the most recently added wave; $p <$
 240 .001). Thus, when age-differences were accounted for, sleep satisfaction and duration were
 241 highly similar between participants who were included and those who were excluded from the
 242 fixed-effects models.

243 Results

244 *Descriptive analyses*

245 Descriptive statistics are presented in Table 1, separately for women and men. On
 246 average, women reported slightly lower sleep satisfaction ($M = 6.65$ vs. $M = 6.98$, $d = 0.15$; $p <$
 247 .001) and almost identical sleep duration compared with men ($M = 7$ h 9 min vs. $M = 7$ h 11 min,
 248 $d = 0.03$; $p < .001$). In both women and men, sleep satisfaction was worse, and sleep duration
 249 shorter, for participants reporting childbirth compared with those not reporting childbirth
 250 (women: $M = 6.58$ vs. $M = 6.66$, $d = 0.04$ and $M = 7$ h vs. $M = 7$ h 10 min, $d = 0.15$, respectively;
 251 men: $M = 6.97$ vs. $M = 7.03$, $d = 0.03$ and $M = 6$ h 59 min vs. $M = 7$ h 13 min, $d = 0.21$,
 252 respectively; all p 's < .01). Participant age was negatively correlated with sleep satisfaction, $r = -$
 253 .10, $p < .001$, and sleep duration, $r = -.04$, $p < .001$. Socio-economic status and homeownership
 254 were associated with sleep satisfaction and duration, although the differences between groups
 255 were very small. Participants above the median monthly household income ($Mdn = 2,500€$)
 256 showed slightly higher sleep satisfaction and slightly longer sleep duration compared with

257 participants below the median (sleep satisfaction: $M = 7.03$ vs. $M = 6.58$, $d = 0.20$, $p < .001$;
 258 sleep duration: $M = 7$ h 8 min vs. $M = 7$ h 12 min, $d = 0.06$; $p < .001$). Homeowners showed
 259 slightly higher sleep satisfaction and slightly longer sleep duration compared to non-homeowners
 260 (sleep satisfaction: $M = 6.94$ vs. $M = 6.65$, $d = 0.13$, $p < .001$; sleep duration: $M = 7$ h 7 min vs.
 261 $M = 7$ h 13 min, $d = 0.08$, $p < .001$).

262 *Course of sleep satisfaction and duration across pregnancy and birth of the first, second,*
 263 *and third child, for mothers and fathers*

264 Fixed-effects regression models showed that for mothers, sleep satisfaction decreased
 265 with pregnancy and postpartum compared with before pregnancy (all p 's $< .001$, see Table 2 and
 266 Figure 1). Compared with the penultimate interview before the respective childbirth, mothers'
 267 sleep satisfaction decreased by an average of 1.53 points on the 0 to 10 scale ($d = 0.67$) after the
 268 birth of their first child, 0.96 points ($d = 0.42$) after the second, and 1.15 points ($d = 0.51$) after
 269 the third. Mothers' sleep duration increased slightly during pregnancy (10 min., $d = 0.14$, $p <$
 270 $.01$) but decreased sharply after childbirth compared with before pregnancy; sleep duration
 271 decreased on average by 41 minutes ($d = 0.59$) after the first child, 39 minutes ($d = 0.58$) after
 272 the second, and 44 minutes ($d = 0.64$) after the third (all p 's $< .001$, see Table 2 and Figure 1).
 273 Four to six years after the birth of their first child, maternal sleep satisfaction and duration were
 274 still lower than pre-pregnancy, after controlling for age (0.95 scale points, $d = 0.42$ for sleep
 275 satisfaction and 22 min., $d = 0.32$ for sleep duration, all p 's $< .001$). The birth of the second and
 276 third children affected mothers' sleep satisfaction significantly less than did the birth of the first
 277 child (all p 's $< .001$), while the effects on sleep duration were similar after the first, second, and
 278 third childbirth (all p 's $> .05$).

279 Consistent with mothers, fathers' sleep satisfaction and duration decreased after
280 childbirth compared with before pregnancy ($p < .05$, see Table 2 and Figure 1) although
281 compared with mothers these effects were significantly smaller (all p 's $< .001$). An exception
282 was fathers' sleep satisfaction after the birth of their third child, when sleep satisfaction no
283 longer showed a significant decrease. In terms of effect sizes and compared to before pregnancy
284 (i.e., at the second to last interview before the respective childbirth), fathers' sleep satisfaction
285 decreased by $d = 0.18$ (0.41 scale points), $d = 0.09$ (0.20 points), and $d = 0.08$ (0.19 points) after
286 the birth of their first, second, and third children. Moreover, fathers' sleep duration decreased on
287 average by 14 minutes ($d = 0.21$), 9 minutes ($d = 0.13$), and 12 minutes ($d = 0.18$) after the first,
288 second, and third child. Four to six years after the birth of their first child, fathers' sleep
289 satisfaction and duration were still lower than their pre-pregnancy values (0.64 scale points, $d =$
290 0.28 for sleep satisfaction and 14 min, $d = 0.21$ for sleep duration, all p 's $< .01$) after controlling
291 for age. The birth of their second child affected fathers' sleep satisfaction less than did the birth
292 of their first child (all p 's $< .05$), while the effect on sleep duration was very similar after the
293 first, second, and third childbirth.

294 *Fine-grained analysis of sleep satisfaction and duration across the three pregnancy*
295 *trimesters and first year after childbirth*

296 Next, we conducted finer-grained analyses focusing on the first childbirth, with indicators
297 for the last quarter year before pregnancy, each of the three pregnancy trimesters, and each of the
298 four quarters of the first year after the child's birth (Figure 2 and Supplemental Materials, Tables
299 S2-S5). There was a decrease in sleep satisfaction across the three pregnancy trimesters in
300 women but not in men. There was no decrease in sleep duration across pregnancy in either
301 women or men. However, there was a clear decrease in sleep satisfaction and duration between

302 the third pregnancy trimester and the first three months after childbirth in both women and men
 303 (all p 's < .001). In terms of the magnitude of change, compared to pre-pregnancy, sleep
 304 satisfaction was 1.81 scale points ($d = 0.79$) lower in women and 0.37 points ($d = 0.16$) lower in
 305 men; sleep duration was 62 minutes ($d = 0.90$) shorter in women and 13 minutes ($d = 0.19$)
 306 shorter in men. Compared to the third trimester of pregnancy, sleep satisfaction after childbirth
 307 was 0.57 points ($d = 0.25$) lower in women and 0.96 points ($d = 0.42$) lower in men; sleep
 308 duration was 87 minutes ($d = 1.27$) shorter in women and 27 minutes ($d = 0.40$) shorter in men.
 309 Between the first three-month quarter and the second three-month quarter after childbirth, both
 310 mothers' and fathers' sleep duration improved (all p 's < .001).

311 *Potential protective and risk factors for mothers' and fathers' sleep satisfaction and*
 312 *duration across pregnancy and after the birth of their first child*

313 Among the variables analyzed as potential protective or risk factors for parental sleep,
 314 maternal and paternal age, household income, and dual parenthood vs. single parenthood (for
 315 mothers) were unrelated to changes in either sleep satisfaction or duration across pregnancy and
 316 in the first year after birth of the first child (see Supplemental Materials, Tables S6-S9).
 317 However, breastfeeding slightly increased the negative effect of childbirth on sleep satisfaction
 318 and duration among mothers (0.72 points, $d = 0.32$ for sleep satisfaction; 14 min., $d = 0.21$ for
 319 sleep duration, all p 's < .01) but not among fathers. Homeownership was associated with slightly
 320 better sleep satisfaction (0.27 points, $d = 0.12$) and slightly longer sleep duration (8 min., $d =$
 321 0.12) in mothers.

322 **Discussion**

323 Our study shows, for the first time with a large population-representative panel study and
 324 a long-term follow-up of more than six years, that maternal sleep satisfaction decreases linearly

325 across the three trimesters of pregnancy and reaches a nadir during the first three months after
326 birth; thereafter, maternal sleep satisfaction improves, though it does not reach pre-pregnancy
327 levels even up to six years postpartum. Maternal sleep duration increases slightly during
328 pregnancy, but in the first three months postpartum women experience, on average, a marked 1-
329 hour reduction per night compared with pre-pregnancy. While sleep duration then increases by
330 around 30 minutes, on average, during months 4–6 postpartum, it does not recover fully to pre-
331 pregnancy levels even up to six years after the birth.

332 After the second and third child, the effects on maternal sleep satisfaction are less
333 pronounced than after the first child. In contrast, maternal sleep duration shows a similar
334 magnitude of change regardless of whether it was after the first, second, or third child. In sum,
335 childbirth causes pervasive sleep effects for women despite being a common life-event. Most
336 intriguingly, our study is the first to show that mothers' sleep satisfaction and duration do not
337 recover to pre-pregnancy levels even up to six years after birth of the first child, having adjusted
338 for maternal age.

339 Changes in paternal sleep satisfaction and duration after birth compared with pre-
340 pregnancy are less pronounced and reach only around a third or less of the effects sizes seen in
341 mothers. This may be associated with the observation that mothers, including working women,
342 still have more household and child rearing responsibilities and spend more time on these tasks
343 compared with fathers in most industrialized countries including Germany^{33,34}. It is possible
344 that an unequal distribution of the burden of child nursing at night favoring fathers is reflected in
345 a less pronounced decline in sleep satisfaction and sleep duration in fathers than mothers after
346 childbirth. However, neither father's sleep satisfaction nor sleep duration reaches pre-pregnancy
347 levels up to six years after the birth of their first child. Taken together, the long-term course of

348 both mothers' and fathers' sleep satisfaction and duration even up to six years following the birth
349 of their first child indicates incomplete recovery.

350 In line with previous research, our findings show a decrease in parental sleep satisfaction
351 during later pregnancy and immediately after childbirth^{1-3, 6-8, 15, 16, 27}, an improvement after the
352 first three postpartum months have passed in mothers^{3, 19}, more pronounced effects in mothers
353 compared with fathers^{17, 18}, and more pronounced effects after the first compared with the
354 second and third child³. The nadir of mothers' sleep satisfaction and duration during the first
355 three months after childbirth coincides with the peak in infant crying³⁵. It is possible that
356 children's increased fussing and crying during the first three months after birth, along with their
357 dependence on frequent nocturnal feedings and other caretaking, are important reasons for
358 parental sleep disturbance after childbirth. Apart from infant crying and frequent nursing, other
359 potential proximate causes of poor postpartum sleep may involve physical pain following
360 delivery and distress related to the demands of a new role. Causes of the long-term decrease in
361 sleep satisfaction and duration till six years after birth may involve changes in duties, strains, and
362 worries related to the parental role even when children are older.

363 One aim of our study was to examine the roles of several potential factors that may be
364 protective of maternal and paternal sleep during pregnancy and postpartum. Our study shows that
365 breastfeeding is related to a slight decrease in maternal sleep satisfaction (0.72 points on the 0 to
366 10 scale, $d = 0.33$) and duration (14 min, $d = 0.21$). This finding adds further evidence to the
367 long-standing question about whether breastfeeding is related to sleep quality, for which
368 previous research has yielded inconsistent findings. Our results are consistent with a study
369 showing more sleep fragmentation among breastfeeding women¹⁵ but they are also in contrast to
370 studies showing no differences in sleep between breastfeeding and non-breastfeeding women³⁶

371 or even longer sleep duration in breastfeeding mothers²⁰. It is possible that these inconsistent
372 findings are due to differences in sample selection. While other studies have examined sleep in
373 convenience samples, the current study included a large sample representative of the adult
374 population in Germany. Further, it is possible that inconsistent findings are due to differences in
375 measurement of sleep (e.g., self-report vs. actigraphy).

376 Towards determining other factors that may protect maternal and paternal sleep
377 satisfaction and duration, we studied socio-demographic (parental age), socio-economic
378 (household income, homeownership), and psychosocial (dual vs. single parenting) factors.
379 Among these, only homeownership emerged as a significant factor for mothers' sleep; however,
380 the effect size was very modest. Our examination of potential protective factors therefore
381 suggests that wealthier parents, parents who are older, and mothers who live with a partner are
382 equally vulnerable to the sleep-impairing effects of pregnancy and childbirth as are less wealthy,
383 younger, and single counterparts.

384 While our study has important strengths, including our examination of a large
385 representative sample and analysis of sleep patterns longitudinally from pre-pregnancy through
386 pregnancy and until six years after childbirth, it also includes some limitations. First, only single-
387 item survey questions were administered. Although there is evidence for reliability and validity
388 of single-item questions about sleep satisfaction and duration^{27, 37, 38} - and objective sleep
389 recordings with samples of this size are impractical - employing objective measures of sleep may
390 nonetheless have strengthened our study. Moreover, it is possible that more sensitive measures of
391 psychosocial support during pregnancy and the postpartum years may have revealed more
392 protective effects on sleep. Relatedly, we could not distinguish between exclusive breastfeeding
393 and breastfeeding supplemented by formula or infants receiving breast milk from the bottle.

394 Second, it is possible that other variables which were not analyzed herein may have moderated
395 the effect of childbirth on sleep, such as bed-sharing (co-sleeping with the infant), duration of
396 family leave, or body mass index. Third, due to the study design, only yearly assessment waves
397 are available. This precludes analysis of changes in sleep across the trimesters of pregnancy and
398 the postpartum quarters in a pure longitudinal analysis. Fourth, while our study shows within-
399 individual changes across time that coincide with pregnancy and childbirth, this does not
400 preclude the possibility that other, unobserved causal mechanisms may have been involved.
401 Finally, it is impossible to exclude the possibility that panel dropout was non-random, which
402 may have affected effect sizes and interpretation of the findings. While sensitivity analyses
403 indicated that there were no sleep differences between participants who continued or dropped
404 out, it is possible that changes in sleep may have occurred after the last interview.

405 In conclusion, our study shows that pregnancy, and particularly the first several months
406 postpartum, are accompanied by a marked decline in parental sleep satisfaction. This is
407 especially true for first-time mothers, for whom childbirth is presumably the most significantly
408 sleep-altering life event during their adulthood. After the birth of a first child, sleep satisfaction
409 apparently does not fully recover to pre-pregnancy levels in either mothers or fathers. It is
410 therefore possible that parenthood contributes meaningfully to the well-documented overall
411 decline in sleep satisfaction during adulthood^{31,32}. We found little evidence for factors that
412 might offset the impacts of pregnancy and childbirth on parental sleep. Higher socio-economic
413 status and dual parenting do not buffer against the decrease in either sleep satisfaction or
414 duration, while breastfeeding and living in a rented flat appear to only slightly amplify the effect
415 on maternal sleep during the first three months postpartum. Because sleep plays an important
416 role for adjustment and mental health during pregnancy and postpartum, it is an important task

417 for future research to examine ways to protect sleep quality and duration in this stage of the life
418 cycle. Furthermore, advice and support should be routinely provided for new parents preparing
419 for childbirth, towards managing their postpartum sleep expectations and to encourage them to
420 take precautions to reduce risks from the effects of sleep fragmentation and deprivation.

421

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424 available by the German Institute for Economic Research (<https://www.diw.de/en/soep>) and our
425 analyses scripts are available on OSF (<https://osf.io/xdgmy/>).

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429

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Figure captions

540 Figure 1. *Sleep satisfaction standardized based on overall sample (A, B, C) and sleep duration in*
541 *hours (D, E, F) of mothers and fathers during years 2 and 1 before birth and during years 1, 2,*
542 *3, and 4-6 following birth of the first (A, D), second (B, E), and third child (C, F). The*
543 *approximate time of birth is indicated by a vertical line. Error bars represent 95% confidence*
544 *intervals of fixed-effects regression coefficients.*

545 Figure 2. *Sleep satisfaction standardized based on overall sample (A) and sleep duration in*
546 *hours (B) for women and men before pregnancy (tri0: trimester 0 including months 1-3 before*
547 *pregnancy), during pregnancy (tri1: months 1-3 of pregnancy; tri2: months 4-6 of pregnancy;*
548 *tri3: months 7-9 of pregnancy), and during the first year of the firstborns life (quart1: months 1-*
549 *3 after childbirth; quart2: months 4-6 after childbirth; quart3: months 7-9 after childbirth;*
550 *quart4: months 10-12 after childbirth). The approximate time of birth is indicated by a vertical*
551 *line. Error bars represent 95% confidence intervals of fixed-effects regression coefficients. Note*
552 *that neighboring confidence intervals are generated by different subsets of participants.*

553

554

Appendix captions

555 *Coding procedure for first, second, and third childbirth*

556

561 Table 1. *Demographic information on participants in the analysis sample.*

	Total	Men reporting no childbirth in study period	Fathers reporting childbirth in study period ^b	Women reporting no childbirth in study period	Mothers reporting childbirth in study period ^b
Number of Participants ^a	38,861	15,837	2,118	18,365	2,541
Number of Observations ^a	190,227	76,655	10,657	89,889	13,026
Age M (SD)	48.77 (17.29)	50.98 (17.67)	36.18 (6.39)	50.68 (17.15)	32.90 (5.69)
% Partner lives in same household	69.43	70.89	94.87	62.59	87.22
Educational attainment					
% Low (ISCED: 0,1,2)	14.28	11.83	9.41	17.47	10.60
% Middle (ISCED: 3,4)	56.11	53.93	52.67	58.35	56.32
% High (ISCED: 5,6)	29.61	34.24	37.92	24.18	33.09
Home ownership (%)	52.12	56.75	42.42	51.30	38.43
Household income after taxes in EUR/month M (SD)	2,942 (1,968)	3,044 (2,053)	3,200 (1,613)	2,812 (1,968)	3,027 (1,638)
Number of participants with sleep satisfaction data (analysis sample for sleep satisfaction)	38,428	15,657	2,097	18,165	2,509
Number of observations regarding sleep satisfaction	186,507	75,052	10,519	88,110	12,826
Number of observations per participant regarding sleep satisfaction M (SD)	4.85 (2.26)	4.79 (2.33)	5.02 (2.02)	4.85 (2.27)	5.11 (2.00)
Sleep satisfaction M (SD)	6.80 (2.27)	6.97 (2.21)	7.03 (2.03)	6.66 (2.35)	6.57 (2.23)
Number of participants with sleep duration data (analysis sample for sleep duration)	35,272	14,326	1,864	16,817	2,265
Number of observations regarding sleep duration	159,802	64,791	8,483	76,206	10,322
Number of observations per participant regarding sleep duration M (SD)	4.53 (1.82)	4.52 (1.87)	4.55 (1.58)	4.53 (1.83)	4.55 (1.56)
Sleep duration M (SD)	7.17 (1.14)	7.21 (1.11)	6.99 (0.93)	7.17 (1.19)	7.00 (1.11)

562 *Note.*563 ^a This number includes participants with longitudinal data on either sleep satisfaction or sleep duration making it larger than the two
564 analysis samples.565 ^b This refers to participants reporting the birth of their 1st, 2nd, or 3rd child.566 ISCED: International Standard Classification of Education, a statistical framework for organizing information on education
567 maintained by the United Nations Educational, Scientific and Cultural Organization (UNESCO).

568 Table 2. *Fixed-effects estimates predicting sleep satisfaction and sleep duration in hours with separate regression analyses for men*
 569 *and women.*

	Sleep satisfaction (unstandardized)		Sleep satisfaction (standardized)		Sleep duration (unstandardized)		Sleep duration (standardized)	
	Men	Women	Men	Women	Men	Women	Men	Women
Person-centered age	-0.041*** (0.003)	-0.042*** (0.003)	-0.018*** (0.001)	-0.018*** (0.001)	-0.019*** (0.002)	-0.029*** (0.002)	-0.017*** (0.001)	-0.025*** (0.001)
Person-centered age squared	0.003* (0.001)	0.002 (0.002)	0.001* (0.001)	0.001 (0.001)	0.002* (0.001)	0.002* (0.001)	0.001* (0.001)	0.001* (0.001)
Year 2 before 1st childbirth	0.105 (0.109)	0.136 (0.106)	0.046 (0.048)	0.060 (0.047)	-0.025 (0.055)	0.055 (0.053)	-0.022 (0.048)	0.048 (0.047)
Year 1 before 1st childbirth	0.078 (0.102)	-0.456*** (0.101)	0.034 (0.045)	-0.200*** (0.044)	0.047 (0.056)	0.164** (0.055)	0.041 (0.049)	0.144** (0.048)
Year 1 after 1st childbirth	-0.414*** (0.095)	-1.533*** (0.093)	-0.182*** (0.042)	-0.674*** (0.041)	-0.240*** (0.051)	-0.676*** (0.050)	-0.210*** (0.045)	-0.592*** (0.044)
Year 2 after 1st childbirth	-0.496*** (0.101)	-1.117*** (0.099)	-0.218*** (0.045)	-0.491*** (0.043)	-0.252*** (0.055)	-0.425*** (0.053)	-0.220*** (0.048)	-0.373*** (0.047)
Year 3 after 1st childbirth	-0.561*** (0.108)	-0.976*** (0.105)	-0.247*** (0.048)	-0.429*** (0.046)	-0.230*** (0.058)	-0.386*** (0.056)	-0.201*** (0.051)	-0.338*** (0.049)
Years 4 to 6 after 1st childbirth	-0.641*** (0.110)	-0.951*** (0.106)	-0.282*** (0.048)	-0.418*** (0.047)	-0.241*** (0.059)	-0.365*** (0.057)	-0.211*** (0.052)	-0.319*** (0.050)
More than 6 years after 1st childbirth	-0.423*** (0.128)	-0.682*** (0.125)	-0.186*** (0.056)	-0.300*** (0.055)	-0.220** (0.069)	-0.321*** (0.068)	-0.193** (0.061)	-0.281*** (0.059)
Year 2 before 2nd childbirth	0.037 (0.099)	0.030 (0.095)	0.016 (0.044)	0.013 (0.042)	0.041 (0.050)	0.067 (0.048)	0.036 (0.044)	0.059 (0.042)
Year 1 before 2nd childbirth	0.130 (0.099)	-0.021 (0.095)	0.057 (0.044)	-0.009 (0.042)	0.003 (0.054)	0.061 (0.051)	0.003 (0.047)	0.053 (0.045)
Year 1 after 2nd childbirth	-0.198* (0.099)	-0.962*** (0.094)	-0.087* (0.043)	-0.423*** (0.041)	-0.143** (0.054)	-0.656*** (0.051)	-0.125** (0.047)	-0.575*** (0.045)
Year 2 after 2nd childbirth	-0.221* (0.105)	-0.437*** (0.100)	-0.097* (0.046)	-0.192*** (0.044)	-0.087 (0.057)	-0.367*** (0.054)	-0.077 (0.050)	-0.322*** (0.047)
Year 3 after 2nd childbirth	-0.064 (0.111)	-0.133 (0.105)	-0.028 (0.049)	-0.059 (0.046)	-0.090 (0.060)	-0.201*** (0.057)	-0.079 (0.053)	-0.176*** (0.050)

Years 4 to 6 after 2nd childbirth	0.086 (0.111)	0.088 (0.105)	0.038 (0.049)	0.039 (0.046)	-0.029 (0.060)	-0.098 (0.057)	-0.026 (0.053)	-0.086 (0.050)
More than 6 years after 2nd childbirth	0.122 (0.131)	0.186 (0.127)	0.054 (0.058)	0.082 (0.056)	0.034 (0.072)	-0.004 (0.069)	0.030 (0.063)	-0.004 (0.060)
Year 2 before 3rd childbirth	0.076 (0.140)	-0.226 (0.133)	0.033 (0.062)	-0.099 (0.059)	0.121 (0.070)	-0.122 (0.067)	0.106 (0.061)	-0.107 (0.059)
Year 1 before 3rd childbirth	0.138 (0.137)	-0.224 (0.130)	0.061 (0.060)	-0.098 (0.057)	0.022 (0.074)	0.014 (0.072)	0.019 (0.065)	0.012 (0.063)
Year 1 after 3rd childbirth	-0.190 (0.129)	-1.154 ^{***} (0.125)	-0.084 (0.057)	-0.508 ^{***} (0.055)	-0.203 ^{**} (0.071)	-0.728 ^{***} (0.069)	-0.178 ^{**} (0.062)	-0.637 ^{***} (0.060)
Year 2 after 3rd childbirth	-0.223 (0.139)	-0.830 ^{***} (0.135)	-0.098 (0.061)	-0.365 ^{***} (0.059)	-0.123 (0.075)	-0.446 ^{***} (0.073)	-0.108 (0.066)	-0.390 ^{***} (0.064)
Year 3 after 3rd childbirth	-0.293 (0.150)	-0.352 [*] (0.145)	-0.129 (0.066)	-0.155 [*] (0.064)	-0.175 [*] (0.081)	-0.310 ^{***} (0.079)	-0.153 [*] (0.071)	-0.271 ^{***} (0.069)
Years 4 to 6 after 3rd childbirth	-0.310 [*] (0.149)	-0.366 [*] (0.144)	-0.136 [*] (0.066)	-0.161 [*] (0.064)	-0.138 (0.081)	-0.223 ^{**} (0.079)	-0.121 (0.071)	-0.195 ^{**} (0.069)
More than 6 years after 3rd childbirth	-0.184 (0.197)	-0.115 (0.193)	-0.081 (0.087)	-0.051 (0.085)	-0.185 (0.108)	-0.191 (0.106)	-0.162 (0.094)	-0.168 (0.093)
Constant	7.199 ^{**} (0.072)	7.102 ^{***} (0.088)	0.176 ^{***} (0.032)	0.133 ^{***} (0.039)	7.324 ^{**} (0.040)	7.431 ^{**} (0.049)	0.136 ^{***} (0.035)	0.229 ^{**} (0.043)
Observations	85,571	100,936	85,571	100,936	73,274	86,528	73,274	86,528
Participants	17,754	20,674	17,754	20,674	16,190	19,082	16,190	19,082

570

Note.

571

Analyses are based on a total of 186,507 observations from 38,428 participants for sleep satisfaction and 159,802 observations from

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35,272 participants for sleep duration (see Supplemental Material, Figures S1 & S2). Standardization is based on these overall

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samples.

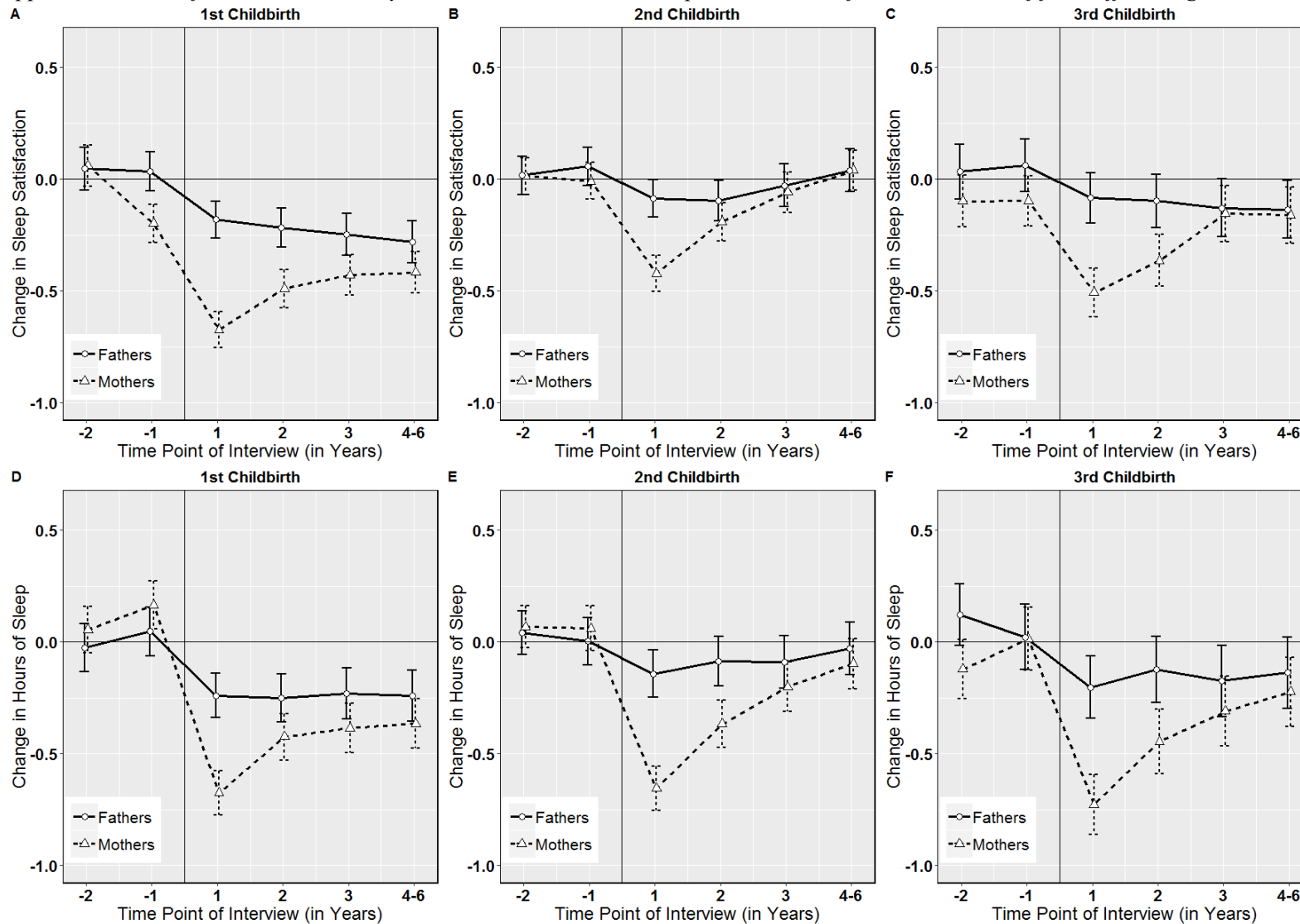
574

Standard errors in parentheses.

575

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

532 Figure 1. Sleep satisfaction standardized based on overall sample (A, B, C) and sleep duration in hours (D, E, F) of mothers and fathers during
 533 years 2 and 1 before birth and during years 1, 2, 3, and 4-6 following birth of the first (A, D), second (B, E), and third child (C, F). The
 534 approximate time of birth is indicated by a vertical line. Error bars represent 95% confidence intervals of fixed-effects regression coefficients.



536 Figure 2. Sleep satisfaction standardized based on overall sample (A) and sleep duration in hours (B) for women
 537 and men before pregnancy (tri0: trimester 0 including months 1-3 before pregnancy), during pregnancy (tri1:
 538 months 1-3 of pregnancy; tri2: months 4-6 of pregnancy; tri3: months 7-9 of pregnancy), and during the first year of
 539 the firstborns life (quart1: months 1-3 after childbirth; quart2: months 4-6 after childbirth; quart3: months 7-9 after
 540 childbirth; quart4: months 10-12 after childbirth). The approximate time of birth is indicated by a vertical line.
 541 Error bars represent 95% confidence intervals of fixed-effects regression coefficients. Note that neighboring
 542 confidence intervals are generated by different subsets of participants.

